THE STRUCTURAL RELATION OF THE PURCELL RANGE AND THE ROCKY MOUNTAINS OF CANADA

FRANCIS PARKER SHEPARD
University of Chicago

It has been found repeatedly, in recent years, that on the flanks of many elongated mountain ranges there are thrust faults dipping in under the range. In the absence of these faults, overturned folds, with their axial planes dipping into the range, and indipping slaty cleavage are common. Partly from observation of this sort, Dr. R. T. Chamberlin developed his hypothesis of the wedge-shaped zones of deformation in mountain building.[1] With this idea in mind, I attempted to determine whether the Rocky Mountain trench, a long, narrow depression between two mountain ranges, would show a connection with this type of structure.

This great valley has a length of about 800 miles. It starts somewhat south of the boundary line between the United States and Canada and runs in almost a straight line to the northwest between the Rocky Mountains on the east and a succession of ranges on the west. From what is known about the trench it has been estimated to have an average width from wall to wall of 5 miles. The portion of the trench which I studied was from Gateway, Montana, at the boundary line, to Golden, British Columbia, 180 miles to the north. Study of the trench has been hitherto quite limited. Dr. Daly's section at the 49th parallel[2] crosses the trench, Dr. Schofield's "Cranbrook Area"[3] borders the west side of it for about 60 miles, and the section along the main line of the Canadian Pacific across the Cordillera, made by Allen and Daly,[4] crosses it about 200 miles north of the boundary. Others have made rapid reconnaissances of the trench.

[1] R. T. Chamberlin, *Jour. Geol.*, Vol. XVIII (1910), p. 228.

[2] R. A. Daly, *Geol. Surv. Can. Mem. 38* (1912).

[3] S. J. Schofield, *Geol. Surv. Can. Mem. 68* (1915).

[4] *Guidebook No. 8*, Congrès Géologique International, 1913.

In the 180 miles which I studied, there are two distinct geographic provinces. In the northern province, which extends as far south as Canal Flats, the trench is drained by the Columbia River which has its source in Columbia Lake just north of the Flats. The valley is narrow, for the most part not more than 3 or 4 miles wide. In part of this northern zone there is a wide valley west of and parallel to the Columbia Valley, which joins the trench at both ends and is only separated from it by a narrow ridge, broken in one place. South of Canal Flats the valley is drained by the Kootenay River, which comes into the trench from the east and flows south. In this portion the trench becomes much wider till it reaches its maximum width of 16 miles at Fort Steele. South of there it contracts rapidly to 5 miles at Bull River, but widens again at Elko and at Gateway.

From what could be deciphered from the stratigraphy, it was found that there are two principal series of rocks represented. One is a great succession of limestones ranging from the upper Cambrian to the Mississippian, but with rather large stratigraphic disconformities. The other series is dominantly clastic, consisting chiefly of various metamorphic phases of sandstone, shale, and conglomerate. It has recently been determined, in at least some cases, to be Cambrian, but probably includes much pre-Cambrian. Probably its age overlaps somewhat that of the limestone series. As shown on the map (Fig. 1), this last series makes up most of the west side of the trench in the northern zone, while the limestones are on the east side and occasionally overlap to the west side. South of Canal Flats the limestone series retreats into the Rocky Mountains, and the clastic series crosses the trench, and occupies a zone about 12 miles wide on the east side. Farther south, between Bull River and Gateway, the limestone series again appears in various hillocks in the trench and in narrow zones along its sides.

Structurally the trench has hitherto been considered as a sort of Graben[1] or at least the product of normal faulting.[2] The results

[1] R. A. Daly, *Geol. Surv. Can. Mem. 38*, p. 600.

[2] S. J. Schofield, "The Origin of the Rocky Mountain Trench," *Trans. Roy. Soc. Can.*, Sec. 4 (1920), pp. 73–81.

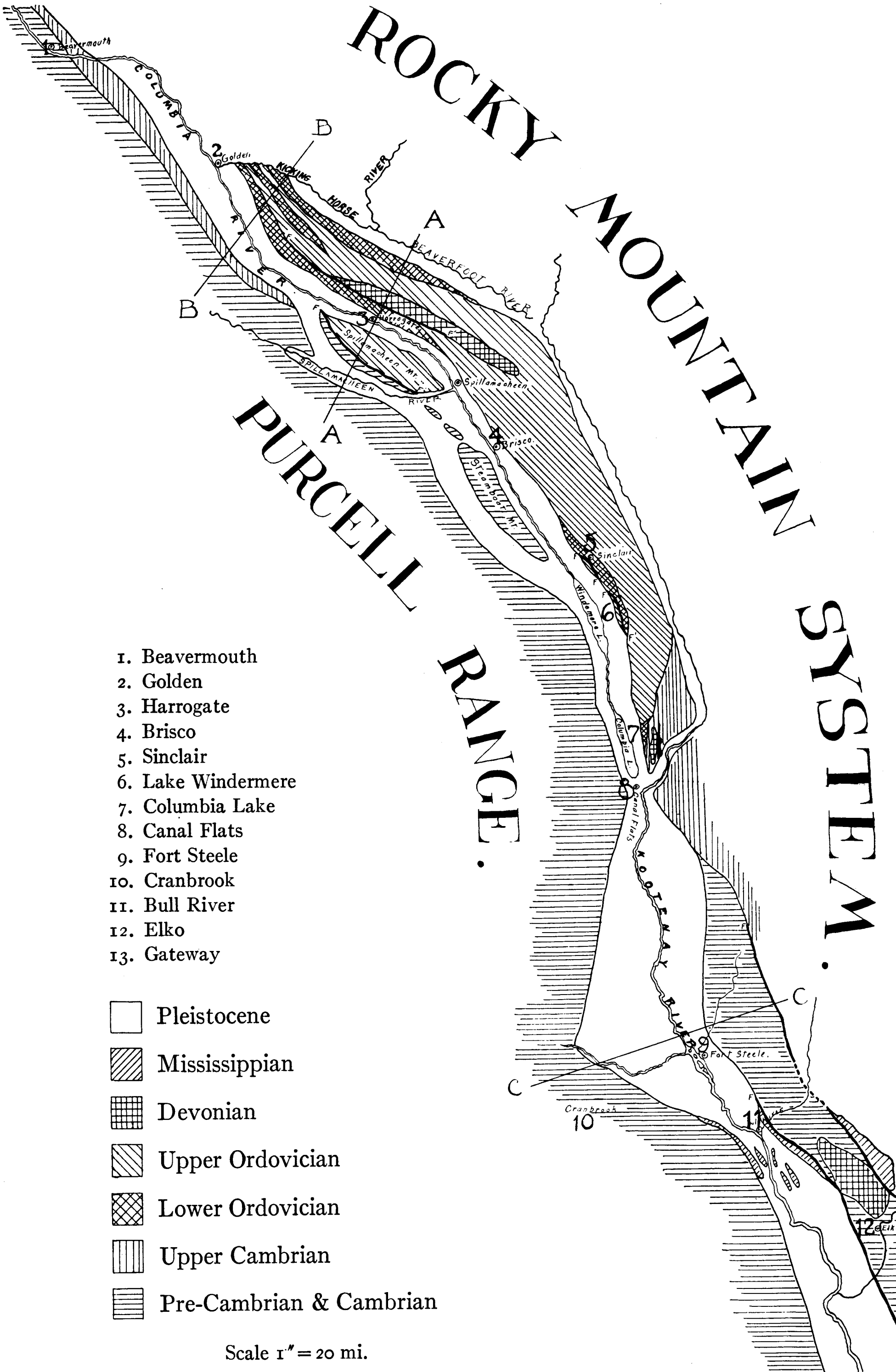

FIG. 1.—South portion of the Rocky Mountain Trench

of my study do not harmonize with this view. The structure should be considered in three divisions.

1. *The northern part.*—In the northern part, the trench is certainly defined by structural features. While the structure varies considerably, there are some features which hold for the entire distance. There is, for example, intense folding on both sides of the trench. The axes of the folds in most cases dip away from the trench, and in places are overturned (Fig. 2).

Most of the faults are thrust faults. On the west side most of these have west-dipping fault planes. On the east, most of the

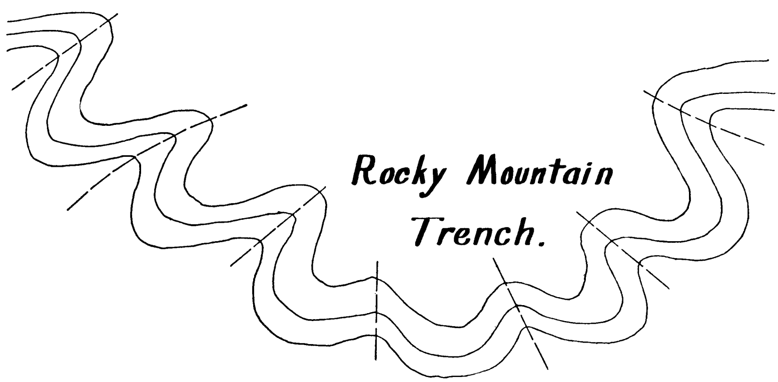

FIG. 2.—Ideal section of folding

thrusts have east-dipping planes. There is a very large thrust fault, which either borders or is found in the trench from Canal Flats almost to Parsons. This fault causes the semimetamorphic series of pre-Cambrian and early Cambrian age to be thrust over against the topmost beds of a thick Ordovician series on the east. At Harrogate (Fig. 3) there are two west-dripping thrust faults each with a displacement of more than 6,000 feet. This great fault probably does not exist north of Parsons. At Beavermouth, 25 miles northwest of Golden, Daly considered that the upper Cambrian-Ordovician series on the east was separated from the Cougar Quartzite on the west by a normal fault of 15,000 feet displacement. In a section in Canyon Creek (Fig. 4) near Golden, the same formations were found as those occurring on the two sides of the fault at Beavermouth, and here there is no fault and the formations follow each other in normal stratigraphic succession.

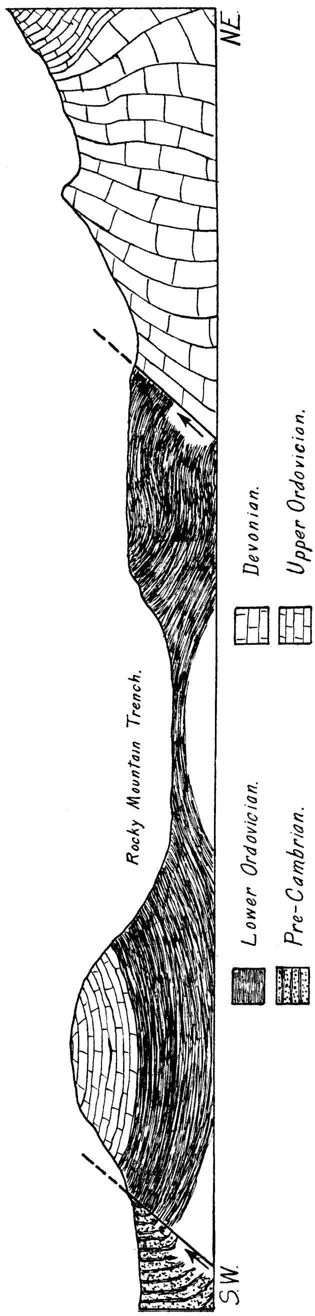

FIG. 3.—Section at Harrogate (through *A—A*, Fig. 1). Scale: 1 inch = 1.06 miles

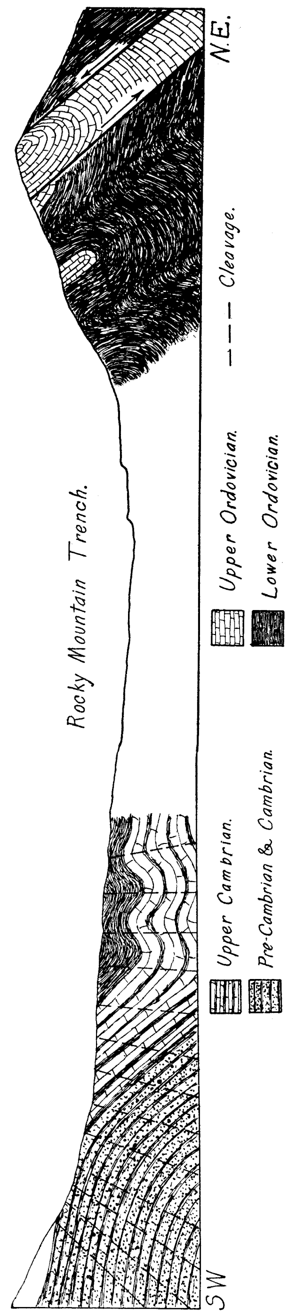

FIG. 4.—Section at Canyon Creek (through *B—B* Fig. 1). Scale: 1 inch = 1.2 miles

At Beavermouth there is a wide zone separating the two series in question, and the fault was inferred entirely on lithological grounds. It seems unlikely that such a fault exists. As will be seen from the section, thrust-faulting on the east is important in this region, which is rather significant in view of the dying out of the west-dipping thrust faults.

In the southern portion of this northern zone there are cases on the east side of the trench where there are intersecting east- and west-dipping thrust faults. In all such cases the west-dipping thrusts cut those from the east. There is an interesting example

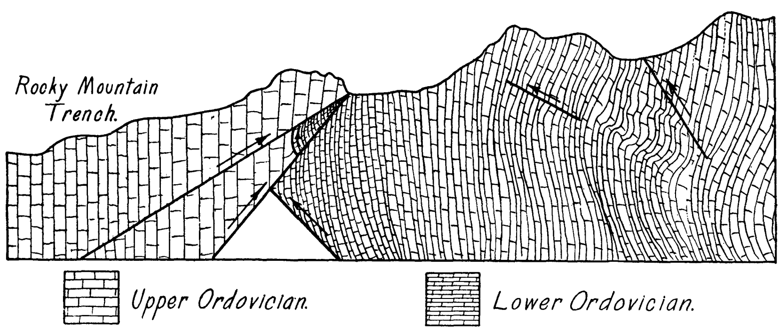

Fig. 5.—Section at Sinclair

of this at Sinclair Springs (Fig. 5). To the east the west-dipping thrust faults always become less conspicuous, and finally die out. At Brisco an east-dipping thrust fault was found on the west side of the trench. Thus there is considerable intersection of the east- and west-dipping thrust faults.

If the general rule for thrust faults is to have dips of much less than 45°, then these faults are exceptional since their dips average about 50° and in some cases are as high as 70°. This is in contrast to the low dips of the thrust faults on the east side of the Rockies in the northern United States and Canada. Experiments, on folding and faulting, which I have made, show that faults which develop at the intersection of two folds may have dips which exceed 45° due to the upward relief being much easier than the lateral. The faults developing between two separate mountain ranges might be subjected to the same influences.

The age of the faulting is not known definitely, but there are several factors bearing on the age, which should be mentioned. In the first place the faulting must have been subsequent to most of the folding in the Rocky Mountains, because in almost no instances are the fault planes involved in the severe folding found on the east side of the trench. The folding of the Rockies is thought to have been mostly during the Laramide revolution. In several cases thrust faults of very great throw were found to exist in such a location that the upthrow side of the thrust is in the valley, while the downthrow side forms the mountain wall (Fig. 3). This feature was found in so many cases that it is obvious that faulting does not directly control the topography. Therefore this faulting must be old. It seems probable that it took place in early Eocene times, at the close of the Laramide deformation. If the overthrusts on the east side of the Rockies are contemporaneous with those on the west, the great amount of subsequent erosion lends some weight to the problem of the age of the Lewis overthrust, which has been considered either early Eocene or Miocene.[1]

The slaty cleavage found in the vicinity of the trench in this section is very constant in character in that it persistently dips to the east on the east side of the trench, while on the west side it dips to the west. Up Canyon Creek, where the section was almost uninterrupted, the cleavage, as shown by the dotted lines (Fig. 4), dips to the west in the Purcell Mountains, becomes gradually vertical toward the middle of the trench, and farther east dips at high angles to the east. Across the trench the cleavage dips to the east at lower angles.

Thus the folding, the thrust-fault system, and the slaty cleavage all point toward the indipping structures and are evidence in favor of Chamberlin's hypothesis of the wedge-shaped deformation masses formed in mountain-building. Here in the trench two intersecting wedges occur, one the Rocky Mountain and the other the Purcell-Selkirk system. The great overthrusts on the east side of the Rockies, such as the Lewis thrust and the Cascade Mountain

[1] B. Willis, *Bull. Geol. Soc. of America*, Vol. XIII (1902), p. 333; R. A. Daly, *Geol. Surv. Can. Mem. 38*, pp. 90–95.

thrust, are examples of indipping structure on the other side of the Rocky Mountain wedge.

The cause of this valley in the northern section is partly the zone of weakness produced by the intersection of such a large number of fault planes, causing erosion to be more rapid here than elsewhere. Also the type of folding on the sides of the trench produced a depression between (Fig. 2).

South of Canal Flats the zone which separates the structure of the Rocky Mountains from the Purcell Range leaves the trench, and swings to the east. This zone does not die out, but appears in the Hughes Range of the Rockies some 12 miles from the trench. It was traced as far south as Elko. In at least two places, this zone has overthrust faults from the west. Fifteen miles up into the

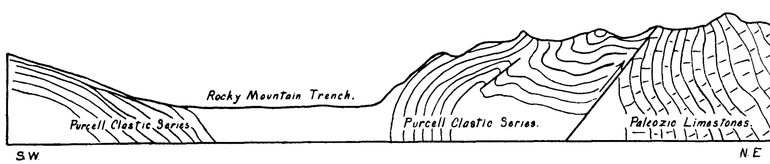

FIG. 6.—Section at Fort Steele (through *C—C*, Fig. 1). Scale: 1 inch = 14.63 miles.

Rockies from Fort Steele, there is an overthrust with a throw of several thousand feet (Fig. 6). No valley exists along this fault, which shows that the faulting does not always control topography.

2. *The central part.*—From Canal Flats to Bull River the trench does not follow structural lines, neither in regard to the strike of the bordering formations, which is roughly parallel on both sides, nor, so far as could be found, in regard to the faults. The conclusion to be drawn from this point is that this part of the trench was developed by a stream flowing on an old erosion surface which was flat enough to allow the river to develop its course independently of structure.

This conclusion is strengthened by several factors. To begin with, the Purcell Range is thought by Schofield[1] to have been deformed in the Jurassic and peneplained in the Cretaceous, and at this time to have developed many valleys out of accord with the structure developed in the Jurassic mountain-building. After the

[1] S. J. Schofield, *Geol. Surv. Can. Mem. 76*, pp. 101–2.

uplift of the Purcell Range, these streams maintained their courses and developed antecedent drainage. That the old Purcell Range existed on both sides of the trench in this zone is evidenced by finding the typical Purcell strike on the east as well as on the west side of the trench. Also the Purcell series (pre-Cambrian) is present on both sides of the trench in this zone.[1]

The great width of this portion of the valley, 16 miles, is out of accord with the rest of the trench, which might be explained by greater age. Also there was found a continuation of the antecedent portion of the trench up into the Purcells leaving the trench in the vicinity of Cranbrook, and it is just south of here that the trench is found to be again connected with structure.

3. *The southern part.*—The southern structural unit extends from Bull River down to Gateway. In this zone there is a thrust fault on the east side of the trench which causes the Mississippian, or in some cases the Devonian, to be brought into contact with the Galton series, partly Cambrian and partly pre-Cambrian,[2] on the east. Large disconformities in this general region make it difficult to estimate the displacement of the fault. It probably is not more than 2,000 or 3,000 feet north of Elko, but at the boundary line it was estimated by Daly[3] to be as much as 10,000 feet. Ten miles south of Bull River it virtually dies out. Here the Devonian limestone comes down from the mountains into contact with the Mississippian in the valley.

This fault, which appears to limit the east side of the trench from Bull River to Gateway, was considered to be a normal fault by both Daly[4] and Schofield.[5] The writer has no definite proof that this is not the case, but there are several facts which suggest that it is a thrust fault. In the first place the trace of the fault plane at Gateway was followed with considerable certainty for several miles, and it was found that the fault plane curved decidedly up a tributary valley to the east (Fig. 7). This, of course, suggests an east-

[1] S. J. Schofield, "The Origin of the Rocky Mountain Trench," *Trans. Roy. Soc. Can.* (1920). P. 76.

[2] S. J. Schofield, *Science*, Vol. LIV, p. 666.

[3] R. A. Daly, *Geol. Surv. Can. Mem. 38*, p. 118.

[4] *Ibid.*

[5] S. J. Schofield, "The Origin of the Rocky Mountain Trench," *Trans. Roy. Soc. Can.* (1920), p. 76.

dipping fault plane. As the upthrow is on the east, the relation is that of a thrust fault.

Also along the eastern wall south of Bull River there is a place where the Mississippian appears to dip under the Galton series on the east. The common occurrence of the east-dipping thrust faults in the northern zone on the east side of the trench suggests the probability of this fault being one of the thrust type. It was thought by Dawson[1] that the fault continued north of Bull River because of a depression along the east side of the valley. The

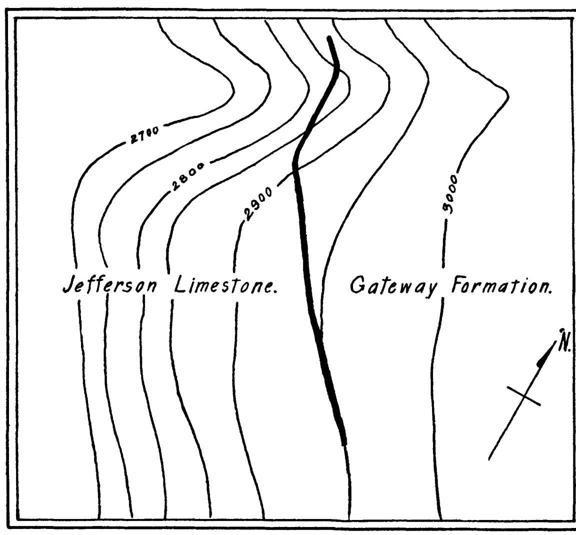

FIG. 7.—Sketch contour map showing trace of fault east of Gateway

writer considers that this depression is one of many instances of drainage along the flanks of the retreating valley glaciers. The valley in this southern section was probably originally defined by this fault plane, and subsequent erosion has broadened the valley chiefly to the west.

In conclusion, the Rocky Mountain trench does not appear to be the unit in its development and structure that it has been thought to be by Daly and Schofield. It appears instead to have been produced partly by normal erosion, partly by erosion along lines of structural weakness, and partly by the escarpment of a fault. Even in this last instance the faulting is probably of the thrust rather than of the normal type.

[1] G. M. Dawson, *Geol. Surv. Can., Ann. Rept.* (1885), p. 190B.